Project Based Learning in Engineering Education at Tromsoe College

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Abstract: The paper describes project as an arena for learning through the tree years (six semesters) of engineering education in computer technology. Project work is about 20 % of the students work in five semesters, and it is 50 % in the last semester.
There are tree categories of projects. The first type, in the first semester, has as its goals to help the students learn project management, teamwork and (as a "spin off") it helps the socialization process of new students. The second type of project is in connection with courses where the project can replace traditional exercises. The third type is realistic projects for external companies. It is possible for a student group to do all the external projects for one institution or company and even working on the same problem. A complete system with user and system documentation can be installed and tested in the user environment. The students have to estimate working hours, and register the number of hours used on each activity, and for each student. The paper gives examples of projects.
The project evaluations are based on the delivered reports (including plans and working documents) and products (software or hardware) and presentation of the project for sensors, lecturer and an audience. In this way, project work even provides a scientific approach to the collection, handling and presentation of information.
We have experienced many benefits of project-based learning. The students will be well prepared for project work when they get a job; they have learned practical routines in companies, and to communicate with customers and users. The students usually work more and get better results in projects than in other courses. Teamwork is also applied in other studies, and team building improves the social life of the students.

Keywords: Project Based Learning, college and industry cooperation, software projects.

1. Introduction

Project Based Learning (PBL) was introduced at the faculty of engineering and economics in 1994. The purpose was to integrate project work in the education, and to make it a new pedagogic method. PBL will also make the students more responsible for their own learning process.

Projects are extensively used in the industry, especially in engineering disciplines like house and ship building, software engineering etc, therefor project work has in some degree been part of the engineering education (main project). In the recent years projects are also introduced in primary and secondary school in Norway.

Our model is built on experience from Aalborg University, Denmark, and the Telemark Model from Telemark College, Norway. The use of this model in engineering education is well documented by Clausen in [1-3].

Details from curriculum and examples presented in this paper are from the computer technology study where I am a lecturer.

2. Project as an arena for learning

There are several definitions of project. From the literature of project work and management we select the definition of project from Jessen [4]. Project work has the following characteristics:

1. *There is a problem or requirement*
2. *A defined goal*
3. *Limited resources are*
    a. *Time*
    b. *Money*

c. People

4. *Some degree of uniqueness*
5. *A result*

Jessen emphasize that project work is an important arena for learning [5]:

> *"The learning process is different form traditional school-based learning. In projects you learn by meeting new problems and challenges. Repeatability is low, and what you learn is less fact oriented. On the other hand you learn a lot about handling new situations, new social relations and handling new problems. – Projects learn you to set focus!"*

At Tromsoe College project are both a learning strategy and training in doing realistic projects like those in industry and business life.

Team building and development of good cooperation skills are important in project work. In the first project when students do not know each other, the advisers set up the groups, while in later projects the students join the groups themselves. The group size is 5 – 7 in the first project, while in the others it is 2 – 5. The most ideal group size is 4 (according to my experience).

The advising of the project groups are more intensive and regular for the first projects, while it is on demand for the later projects. External projects are also advised of the contact person or employer in addition to the internal advisor. Some groups prefer (and need) regular (short) advisory meetings in every project!

There are tree categories of projects. The first type, in the first semester, has as its goals to help the students to learn project management, teamwork and (as a "spin off") it helps the socialization process of new students. The second type is in connection with courses where the projects can replace traditional exercises, and will sometimes be referred to as "problem based learning". The third type of project is realistic projects for external institutions or companies.

3. Organization of PBL

Projects are integrated in the curriculum in the three years of engineering education. In the computer technology study projects is ca. 20 % of the students work in 5 semesters, and 50 % in the last semester.

The Norwegian engineering education last for 3 years, each year is divided in 2 semesters and the semesters are numbered from 1 to 6. The courses are assigned credit points ("vekttall"). The normal workload for a student is 10 points pr. semester.

The following table gives an overview of curriculum, credit points in parenthesis, and project-based courses are marked P.

Table 1. Curriculum for Computer technology study

1st semester	2nd semester	3rd semester	4th semester	5th semester	6th semester
-Mathematics and statistics (4) -Object oriented programming (1) -Information Technology (2) -Project Management (3,P)	-Mathematics and physics (4) -Object oriented programming (continued, 3, P) -Chemistry and Environmental Science (3)	-Mathematics 2 (2) -Algorithms and Data Structures (3) -Computer Architecture (5, P)	-Operating Systems (3) -Software Engineering (4,P) -File and Database Systems (3)	-Introduction to business economics (3) -Data Communication (4) -Software Engineering Project (2,P) -Optional Subject (2)	-Construction of microprocessor systems (3) -Optional Subject (2) -Main Project (5,P)

In the following subsections we give a description of the projects in each semester.

3.1 Project management

The goal of this course is to learn the students project work and management and teamwork. There is an introduction with lectures in general project theory, including project planning and control. All the new students of the faculty take this course. Each project group is put together of 5 – 7 students from different engineering and economy studies. Topics for this project of the first type are from ethics, natural resources or politics. Because of the high number of groups, there are a high number of advisors who have to cooperate, and therefore this project is an arena for new lecturers to learn project advice, and to test new methods.

3.2 Object oriented programming

The first part of the course is traditional lectures and exercises, and the project in the last part of the course in 2nd semester is to solve a large programming problem as a team work, usually there are 4 to 6 members in each group. This and the following project is of the second type.

3.3 Computer architecture

This course has an introductory part with lectures in basic hardware theory, and the project is a study of a particular architecture and assembly programming.

3.4 Software engineering

This course has an introductory part with lectures in software engineering theory, including different models for software engineering projects. The projects are realistic software engineering project for external institutions or companies, and can be a complete development of a small system, or the first version or prototype of a larger system. This project is of the second type (it replaces exercises), and it is also a smooth transition to the third type because it is external. The following two projects are of the third type.

3.5 Project in software engineering

This project is external, and can be a new project, or the next version or activity of the previous, and/or start of the main project. The goal is that the students have to use knowledge from all the previous courses, especially from database and software engineering.

3.6 Main project

The main project is also external, and can be a new project, or the next version or activity of the previous project.

4. Project evaluation

Project evaluation is based on the project report, oral presentation and questioning, and demonstration of software or other products from the projects. In the first project (in "Project management") the advisor will also evaluate the project process. This evaluation is based on regular meetings with the group, and control and feedback on project log (diary) and minutes.

During the oral presentation the group members will have equal time for presentation. It is possible to examine each group member separately when it is obvious that it is great difference in each member's contribution to the result.

The first project is evaluated to pass/fail while the other five are evaluated with individual degree.

5. Examples of projects

This section gives examples of main projects from this semester (finished in April 2000).

5.1. Midnight Sun Marathon

Midnight Sun Marathon is arranged every year in July in Tromsoe in the middle of the night, and hopefully in midnight sun! There are other distances too (half marathon, 10.000 meter etc.) The organization committee asked me in June 1999 if a student group could make a new software system for management of the competition. The old system was DOS-based and not prepared for "Y2K" (a well-known situation!).

Basic requirements for the new system: Multi-user, client-server Oracle data base system, the server running NT operating system and clients running Windows. The system will register all the participants in several classes and distances, generate start numbers, getting time information from the clock, making result reports, give the speaker information etc.

A group of five students started the project in fifth semester ("Project in Software Engineering") in September 1999. They had to define several learning goals: Set up and run an Oracle database server on NT platform, learn to use development tools etc. The requirement specification based on input from the committee and tests of the old system was also written. The group got some help and instructions (on Oracle problems) from one of the sponsor companies (Telenor).

The system was implemented in the sixth semester in "Main Project". It was tested under realistic conditions in March in a cross-country skiing race for children. After some modifications, the system was delivered in April, and is now running in the sponsor's environment where they are registering the competitors. This sponsor will run the system under this years competition 1 July.

In addition to the new system and documentation [6], the project had great learning value for the students, and one of them are employed by the sponsor. The organization has also asked for a new project on extending the database to include all results from all previous competitions, and make it accessible from Internet. Other organizations have asked for the system, so if everything is functioning successfully in July, the system has a commercial potential!

5.2 Database of Mutated Proteins

This project started when professor Oyvind Edvardsen, University of Tromsoe asked for help to improve a database with data about mutated proteins. The database is accessible from Internet and is used for research in pharmacy.

Requirements for the new system included construction of an Oracle database, running on a Linux server, and making new Internet user interface.

The project group of four students had to define learning goals including installation and running of Linux operating system and Oracle database system, and using several tools for development of database, application and web. The project started in September 1999 in "Project in Software Engineering" and was finished in April (2000) as "Main Project" [6]. The database is completed, but there are still more to do with the web user interface. Hopefully a new group will continue with the project from September 2000. We are also invited to cooperation in research projects.

5.2 Projects for Andoya Rocket Range

Andoya Rocket Range (ARR) is a permanent launch range for sounding rockets and scientific balloons. On the range there are instruments giving environment data supporting the rocket launching. Those include magnetometers (measuring the geomagnetic field) and riometers (Relative Ionospheric Opacity Meter measuring cosmic radio noise, which indicates the ion density of the atmosphere).

The first project started in September 1998 and was finished in May 1999. Two students made a system to collect data in real time from the instruments, and store the data on an NT server. The system was developed in Visual C++, and it is now running on ARR [8].

The next project for ARR started in September 1999 and was finished in April 2000. A group of four students has developed (client) software for accessing and displaying data from the server, both from files and in real time [9].

ARR has always a need for new software, so there will be projects for new student groups in the future. Andoya is so far from Tromsoe that it is impossible to have regular project meetings, so most of the communication is via Internet (e-mail).

6. Evaluation of PBL

This section gives a summary of some of our experiences form project based learning.

6.1 Positive experiences from PBL.

The six projects give the students good experience in project work, planning and management. Report writing and oral presentation of project result improves significantly from the first project to the last, and they develop high quality and creativity in using tools for presentation. The exam results are usually better from PBL courses than from traditional courses.

As shown earlier, it is possible to work with the same project for up to three semesters ("Software Engineering", "Project in Software Engineering" and "Main project"). This gives the students the challenge to develop relatively large software systems that can be tested both in the lab and in the user environment. This gives the students extensively experience in software engineering much like how it is done in the industry.

Project work gives a better studying environment. The project planning and management implies that the work is partitioned in activities, milestones are defined and it is controlled that they are reached in time. An important and critical part of software engineering (and other engineering disciplines) is estimation of effort (work hours) on the activities, and to evaluate the estimation, the students have to register time lists. The work is done evenly through the semester, and the group members are responsible for the activities and to share the work fairly.

The students will be more responsible for their own learning process. Problems in the project require new knowledge, new methods, new tools or deeper insight in theory, and they have to define their own learning goals.

The project group gives the new students a good start in building a social network (and friendship), and often the group works together in other courses. In the last two years it is often that the group works together on several projects. To formalize the working discipline in the group, we recommend that the members assign a contract where they define meeting time, working hours and decision process. There will also be rules for exclusion of members that do not work (hard enough)!

External projects are originated from companies contacting the college, or the teachers use their network of contacts and connect the student group to the "employer". Sometimes the students have contacts from working experience, friends or family members who has problems that are adequate for a project. (Every company need for new software!) The college is working on establishing more formal cooperation contracts with companies in the region, and projects will be one of the issues.

The greatest advantages for the company will of course be if the project results in a complete new product or software system. But even a prototype or a well-documented requirement specification will be of high value for the company. And one project in a company will often result in a new project in the next semester, either for the same group or a new one. The new project can be either the next activity of the former, a new subsystem that will be integrated in the former system, or a complete new system or product.

The contact between students and industry has resulted in employment of students. The employer knows the student and his skills, and if a product or system is delivered, it is useful to have someone who can do maintenance. The student knows the company, and will get a better start in the job.

The teachers/advisors have advantage of the contact with the industry, and they learn about their business and demands for competence and new products or systems. This knowledge is used in improving the engineering education. The advising situation demands new skills and challenges of the teachers.

6.2 Problems and negative experiences from PBL

We have of course observed problems with PBL, and we are continuously trying to improve the model and solve the problems. This section comments on some of the problems.

Cooperation problems in groups, for instance when members do not contribute to the work, deliver results in time or participate in meetings. If the group cannot solve the problem, the advisor can help, and eventually reschedule the project and make more formal contracts. If those actions do not help, the ultimate result is that the student drop out or is excluded from the group.

The group accepts that members don't do their job and cover up for them. The adviser has to control the activity and responsibility lists, and time lists. The questions during the oral presentation will also identify each member's contribution to the result, and will result in different grades, or in worst case the student do not pass the exam.

In a few cases the cooperation problems have been unsolvable and the group have split up. If it is too late to build new groups, it has been necessary to accept individual projects.

The project is too difficult or too large, or external problems make it impossible to carry out the project according to the original goal and plan. We can then try to redefine the problem, or narrow the scope of the project. In external software projects it is often useful to define a priority list of the functions, and/or to isolate a kernel system. It is an alternative to let the group continue and do the best out of the situation even when it is obvious that the project will fail. A well-documented fiasco project can be very instructive and it is better to do it as students than in a job!

The external industry partner has not time to follow up the students, answering questions or give feedback on work done or delivered subsystems. The adviser can ask for a meeting with the company, and try to get commitment on feedback, or he can try to help the students by acting as the employer.

7. Conclusions

Project Based Learning gives the engineering students a better preparation for working life than (only) traditional education. PBL will also be more extensively used in the Norwegian education system in the future.

Realistic external projects promote the cooperation between the education institutions and the industry.

8. References

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